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Generation of Realistic Air Traffic Scenarios Based on Recorded Field Data

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Abstract
This paper presents a unique methodology to generate air traffic control scenarios for the support of the testing and analysis of Air Traffic Management decision support tools. This methodology was developed by the Federal Aviation Administration's Engineering and Integration Services Branch (ACT-250) at the William J. Hughes Technical Center. The individual flights within the scenarios generated by this methodology follow realistic flight routes, yet the air traffic in these scenarios contain aircraft-to-aircraft and aircraft-to-airspace conflicts that do not exist in the field. Scenarios with these characteristics are necessary to evaluate decision support tools that predict conflicts.

Background
The Federal Aviation Administration's Free Flight Phase One Program Office tasked the Engineering and Integration Services Branch (ACT-250) at the William J. Hughes Technical Center to supply Lockheed Martin Air Traffic Management Division (LMATM) with scenarios supporting the accuracy testing of the User Request Evaluation Tool Core Capability Limited Deployment (URET CCLD) system. URET CCLD is the operational implementation of the URET decision support tool, which was developed by MITRE and is currently in daily use at the Indianapolis and Memphis En Route Air Traffic Control Centers (ARTCCs). The scenarios are based on field data recorded at these ARTCCs.

The objective of this accuracy testing is to quantify the missed and false aircraft-to-aircraft and aircraft-to-airspace conflict predictions made by URET CCLD. This requires test scenarios containing a significant number of conflicts. However, scenarios generated directly from the recorded field data would not contain conflicts, since the air traffic

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controllers had managed the airspace to avoid such conflicts. Therefore, it was necessary for ACT-250 to modify the recorded field data to induce the required number of conflicts, while at the same time retaining the realism of the air traffic.

Scenario Generation Process

As depicted in Figure 1, the scenario generation process developed by ACT-250 consists of three basic steps: data extraction, data modification, and scenario generation.

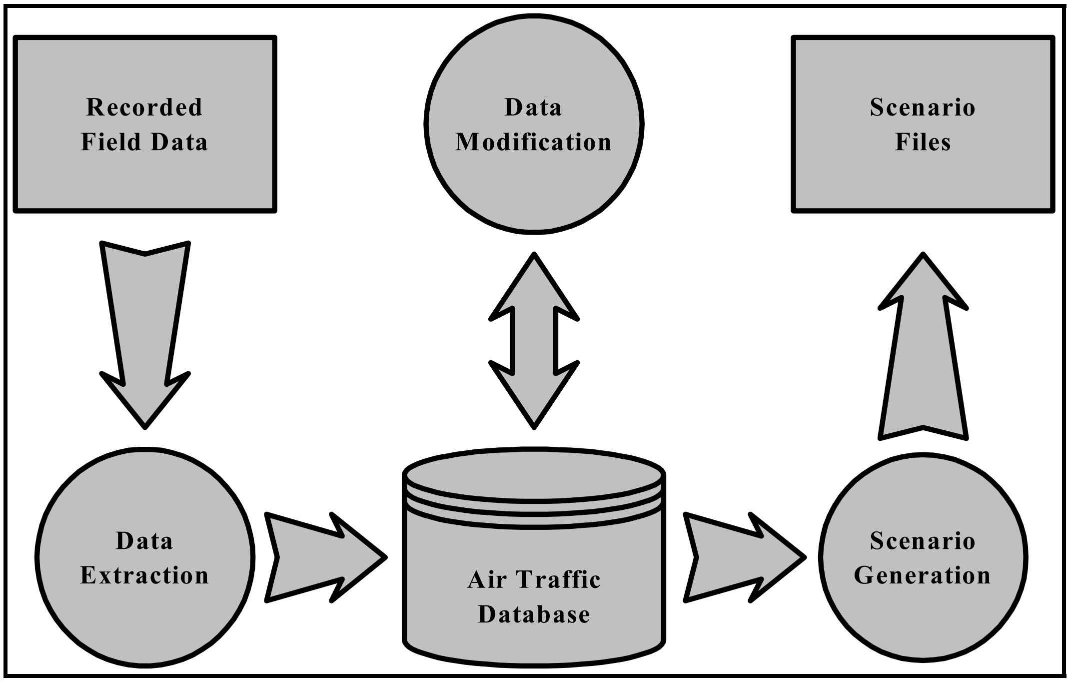

Figure 1: Scenario Generation Process

Data Extraction

The first step of the scenario generation process uses software developed by ACT-250 to extract the data from the field recordings and populate an Air Traffic Database on an Oracle V8.1.5 database management system. This database consists of the twelve tables presented in Table 1. These tables are grouped into three categories: environmental tables, bookkeeping tables, and flight-centric tables.

The concept of flight-centricity is key to the scenario generation process. During data extraction a flight is inserted into the database for each unique flight encountered in the recorded field data that had a flight plan message. Each of these extracted flights has a start time, which is the time of the flight's first recorded track message. All other events (e.g., flight plan messages, hold messages, interim altitude messages, and individual track messages) associated with the flight are relative to this start time. Each flight also has a delta time that is used to time-shift the flight. During the data modification step an entire flight can be shifted in time but retain its flight profile merely by adding this delta time to the flight's start time.

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Table 1: Air Traffic Database

Table Category	Table Name	Table Description
Environmental tables, which contain center specific and operational data. This includes coordinate conversion constants and preferential routing, sector assignment, and route status information.	*fd_airspace*	The *fd_airspace* table contains the constants required for x-y to lat-long coordinate conversion for a specific air traffic control facility.
	fd_rtix	The *fd_rtix* table contains the preferential routes names, indices, and types.
	fd_sector_asgn	The *fd_sector_asgn* contains information associated with the sector assignment messages.
	fd_route_status	The *fd_route_status* table contains information associated with the route status messages.
Bookkeeping tables, which contain data set and run identification information used internally by the software.	*fd_data_id*	The *fd_data_id* table contains information about a specific data extraction.
	fd_run	The *fd_run* table contains information identifying the data sets to be used for a specific run.
Flight-centric tables, which contain flight data such as flight plan information, track data, and controller information messages.	*fd_flight*	The *fd_flight* table contains the static information related to a flight.
	fd_flight_plan	The *fd_flight_plan* table contains a history of the flight plans for a flight.
	fd_track	The *fd_track* table contains the individual track points for a flight.
	fd_int_alt	The *fd_int_alt* table contains a history of the interim altitude messages for a flight.
	fd_hold	The *fd_hold* table contains a history of the hold messages for a flight.
	fd_pref_route	The *fd_pref_route* table contains the converted route information for a flight.

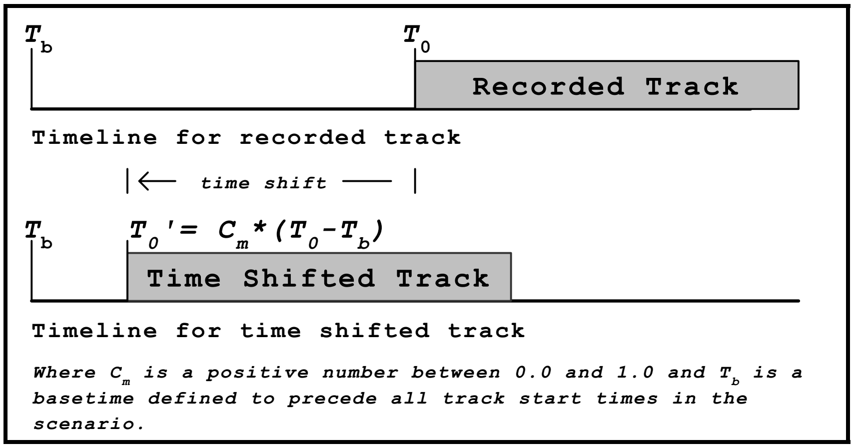

Figure 2: Time Compression

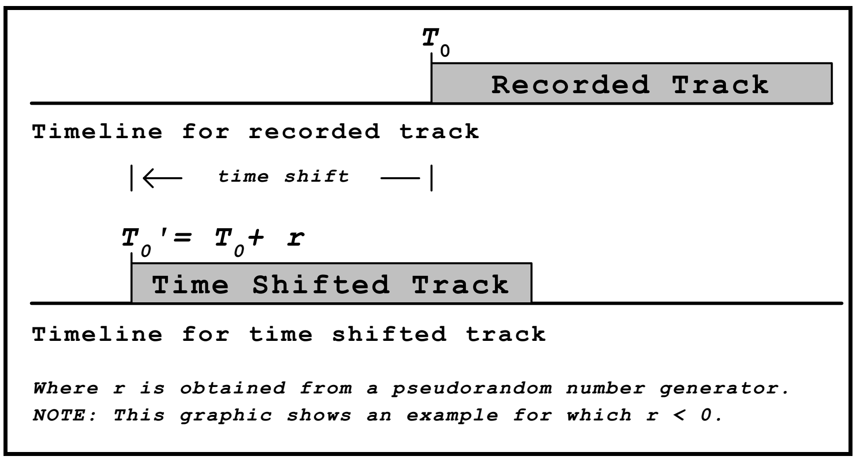

Figure 3: Random Time Adjustment

Data Modification

The second step in the scenario generation process is data modification, which for this task consists of time-shifting the flights. Time-shifting, as implemented in the software developed by ACT-250, consists of combining two independent techniques: time compression and random time adjustment. Time compression causes aircraft-to-aircraft conflicts and increases the flight density, while random time adjustment causes aircraft-to-aircraft and aircraft-to-airspace conflicts.

For time compression, a compression constant (C_m) is multiplied times the difference between the original start time of a flight and a base time that precedes all flights in the scenario. In Figure 2, T_b represents the base time, T_0 represents the flight's start time, and the block labeled *Recorded Track* represents the flight's flight-centric data. With time compression, the flight's original start time, T_0, is changed to T_0' using the equation: $T_0' = T_b + C_m * (T_0 - T_b)$. Note with time compression the flights are always moved earlier in time and the sequence of flights in the scenario is left unchanged.

For random time adjustment, the start time of a flight's track is modified by adding a random time increment. In Figure 3, the start time of the original track, T_0, is changed to T_0' by adding a random variable r, where r is randomly selected from some known frequency distribution (e.g., normal or uniform). Note with random time adjustment the sequence of the flights is changed.

ACT-250 conducted a study to evaluate the affect of time-shifting on trajectory prediction. It was determined flights could be shifted up to one hour without affecting trajectory accuracy [1]. Therefore, ACT-250 ensured that all flights were shifted earlier in time and no flight was shifted by more than one hour. This was done by first compressing the flights by using a compression multiplier that caused the flights to be time-shifted by no more than 30 minutes and then randomly moving the compressed flights earlier in time by selecting a random variable from a uniform distribution in the interval of –1800 seconds to 0 seconds.

Scenario Generation

The final step in the scenario generation process is the actual generation of the scenarios using the time-shifted data. These scenarios are created in multiple formats, including the binary formatted files used by LMATM for the accuracy tests and ASCII formatted files used by both LMATM and ACT-250 as input to other test tools.

Results

ACT-250 used this methodology to generate six 5-hour scenarios that were provided to LMATM for accuracy testing of URET CCLD. It was also used to develop two 2.5-hour scenarios for the Memphis, Indianapolis, and Kansas City ARTCCs, which were provided to LMATM for risk reduction studies. Additional risk reduction scenarios are planned for the Washington and Atlanta ARTCCs.

Future Work

The current scenario generation process can be expanded by developing software capable of populating this database from a variety of sources, which could include field recordings from operational en route and terminal air traffic control facilities or from decision support tool test beds. Other techniques, besides time-shifting, could also be developed to modify the data to meet specific requirements, including optimization techniques such as the genetic algorithm that can produce specific air traffic characteristics. Scenario generation programs, capable of creating scenarios for specific simulation systems, can then be developed.

References

1. Paglione, Mike M., Oaks, Robert D., Ryan, Dr. Hollis F., Summerill, J. Scott, *User Request Evaluation Tool Daily Use Time-shifting Trajectory Prediction Accuracy Degradation Study*, December 15, 1999.